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FINAL TECHNICAL REPORT

1. Title: Gravity Wave Forcing and Influences Near the Mesopause

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2. Research Objectives

Our goals in this research were to address gravity wave effects near the mesopause using largely analytic and modeling techniques. A first approach employed an analytic description of the gravity wave field to develop a parameterization scheme for the most important wave effects at greater altitudes that was based on the observed characteristics of the wave spectrum. A second approach was intended to apply pseudo-spectral collocation techniques for studies of wave excitation, instability, dissipation, and interaction processes thought to play important roles in the circulation, structure, and variability throughout the atmosphere. As seen below, these goals were accomplished.

3. Research Results

The contributions made in each of the major areas of proposed research are described separately below. These include analytic source studies, gravity wave instability modeling, and parameterization development.

a. analytic gravity wave source studies

A study of gravity wave forcing in the middle atmosphere by a solar eclipse followed our earlier use of Fourier integral and Green's function techniques to assess the potential for gravity wave generation by geostrophic adjustment processes. This approach was taken as most previous efforts have focussed on excitation of gravity

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c. modeling achievements

Under SDIO/IST and NRL support, we have developed 2-D and 3-D nonlinear, compressible pseudo-spectral collocation codes in association with Norwegian colleagues and applied them in studies of gravity wave breaking, instability, and turbulence generation relevant to the middle atmosphere. The code capabilities and the results obtained are summarized below.

Our initial gravity wave breaking simulations focussed on a wave motion with a high intrinsic frequency in order to limit the computer resources required to describe the evolution. We also performed parallel simulations in two and three dimensions in order to quantify the different influences on the incident wave amplitude and fluxes and to assess the validity of the 2-D results. Our simulations revealed dramatic differences in the two evolutions, suggesting that gravity wave instability is inherently 3-D and that 2-D models are unable to follow the physics of the wave breaking process or predict the influences on wave amplitudes, transports, or turbulent mixing. A comparison of the 2-D and 3-D results and an assessment of the instability structure and its effects were provided by Andreassen et al. (1993) and Fritts et al. (1993). Vortex breakdown and the subsequent evolution toward smaller, more isotropic scales were discussed by Isler et al. (1993).

Whereas instability in the 2-D simulation was confined to the plane of wave propagation (artificially), 3-D instability was found to comprise counter-rotating vortex structures aligned along the direction of wave propagation and elongated along the unstable phase of the incident wave motion. Relative to the 2-D results, the 3-D wave structure experiences rapid collapse and strong amplitude limits, supporting the convective adjustment hypothesis and suggesting that 2-D simulations are unable to describe the physics of the wave breaking process or the implications for wave and turbulent transports. Dramatic differences in the 2-D and 3-D evolutions are also apparent in the transports of energy and momentum and in the evolution of eddy kinetic energy, providing further evidence that 2-D simulations are not suitable for studies of gravity wave interactions, instability, or induced mixing processes in the middle atmosphere.

4. Publications Citing this SDIO/IST and NRL Support

- Fritts, D. C., 1993: Gravity wave sources, source variability, and lower and middle atmosphere effects, Coupling Processes in the Lower and Middle Atmosphere, NATO ASI Workshop, **387**, 191-208.
- VanZandt, T. E., and D. C. Fritts, 1993: Spectral estimates of gravity wave energy and momentum fluxes, Coupling Processes in the Lower and Middle Atmosphere, NATO ASI Workshop, **387**, 261-290.
- Fritts, D. C., and Z. Luo, 1993: Gravity wave forcing in the middle atmosphere due to reduced ozone heating during a solar eclipse, J. Geophys. Res., **98**, 3011-3021.
- Fritts, D. C., J. R. Isler, G. E. Thomas, and Ø. Andreassen, 1993: Wave breaking signatures in noctilucent clouds, Geophys. Res. Lett., **19**, 2039-2042.
- Fritts, D. C., and T. E. VanZandt, 1993: Spectral estimates of gravity wave energy and momentum fluxes, Part I: Energy dissipation, acceleration, and constraints, J. Atmos. Sci., **50**, 3685-3694.
- Fritts, D. C., and W. Lu, 1993: Spectral estimates of gravity wave energy and momentum fluxes, Part II: Parameterization of wave forcing and variability, J. Atmos. Sci., **50**, 3695-3713.
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- Andreassen, O., C. E. Wasberg, D. C. Fritts, and J. R. Isler, 1994: Gravity wave breaking in two and three dimensions, 1. Model description and comparison of two- and three-dimensional evolutions, J. Geophys. Res., **99**, 8095-8108.
- Fritts, D. C., J. R. Isler, and O. Andreassen 1994: Gravity wave breaking in two and three dimensions, 2. Three-dimensional evolution and instability structure, J. Geophys. Res., **99**, 8109-8123.
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- Fritts, D. C., 1994: Gravity wave-tidal interactions in the middle atmosphere: Observations and theory, The Upper Mesosphere and Lower Thermosphere, Chapman Conf. on the Upper Mesosphere and Lower Thermosphere, in press.
- Luo, Z., D. C. Fritts, R. L. Portmann, and G. E. Thomas, 1994: Dynamical and radiative forcing of the summer mesopause circulation and thermal structure, Part II: Seasonal variations, J. Geophys. Res., submitted.